Department of the Interior
U.S. Geological Survey

USER GUIDE

LANDSAT LAND DATA OPERATIONAL PRODUCT EVALUATION (LDOPE) TOOLBELT

LANDSAT 8 OPERATIONAL LAND IMAGER (OLI) QUALITY ASSESSMENT (QA) BAND SUPPORT

Version 1.0

July 2013

Document History

Document Version	Publication Date	Change Description
1.0	07/12/2013	Initial Version

Contents

Section 1 **Introduction**

Scenes from Landsat 8's Operational Land Imager (OLI) instrumenteach include a Quality Assessment (QA) band. Each pixel in the QA band contains a decimal value that represents bit-packed combinations of surface, atmosphere, and sensor conditions that can affect the overall usefulness of a given pixel.

The bit-packed information in a QA band is decimal translation of binary strings. For example, the decimal value "1" translates to the binary value "0001." The binary value "0001" has 4 bits, written right to left as bits 0 ("1"), 1 ("0"), 2 ("0"), and 3 ("0"). Each of the bits 0-3 represents a condition that can affect the calculation of a physical value. Bit 0 may be used to identify fill values, bit 1 may be used to identify a cloud, bit 2 may be used to indicate water, and bit 3 may be used identify snow. If the condition is true, the bit is set to "1," and "0" if false.

In the example, "0001" means the pixel contains a fill value, and should likely be ignored.

- Bit 0 = 1 = fill
- Bit 1 = 0 = no cloud
- Bit 2 = 0 = land
- Bit 3 = 0 = no snow

Rigorous science applications seeking to optimize the value of pixels used in a study will find QA bits useful as a first level indicator of certain conditions. Otherwise, users are advised that this file contains information that can be easily misinterpreted and it is not recommended for general use.

National Aeronautics and Space Administration (NASA) funded the MODIS Land Data Operational Product Evaluation (LDOPE) team to develop manipulation, visualization, and analysis tools for the MODIS user community. The resulting MODIS LDOPE Toolbox has been distributed without restriction since 2004 from the Land Processes Distributed Active Archive Center (LP DAAC).

A subset of the MODIS LDOPE Toolbox is packaged by the USGS as the Landsat LDOPE (L-LDOPE) Toolbelt (http://landsat.usgs.gov/L-LDOPE_Toolbelt.php), and contains several functions applicable to high-level Landsat 5 and 7 data products, such as Surface Reflectance. Based on the "unpack_sds_bits" function found in the L-LDOPE Toolbelt, a specific tool has also been developed to support Landsat 8 OLI QA. This User Guide describes its functionality.

All original code and documentation are used with permission from LDOPE and are available from LP DAAC at https://lpdaac.usgs.gov/tools/ldope_tools (last accessed December 12, 2012).

Section 2 **Data Characteristics**

Landsat 8 Level 1 data products include a 16-bit QA file in Geographic Tagged Image File Format (GeoTIFF). Robust image processing software capable of handling 16-bit data is necessary to compute statistics of the number of pixels containing each of the designated bits.

Used effectively, QA bits improve the integrity of science investigations by indicating which pixels might be affected by instrument artifacts or subject to cloud contamination. For example, NDVI calculated over pixels containing clouds will show anomalous values. If such pixels were included in a phenology study, the results might not show the true characteristics of seasonal vegetation growth. Cloud contaminated pixels will lower NDVI values, and measures like the timing of 'green up' or peak maturity would appear later than they actually occurred. A worse consequence would be that the reported reduction of vegetation growth would be taken as an indicator of environmental change, potentially prompting unnecessary land management policies or practices.

The pixel values in the QA file must be translated to 16-bit binary form to be used effectively. The gray shaded areas in the table below show the bits that are currently being populated in the Level 1 QA Band, and the conditions each describe. None of the currently populated bits are expected to exceed 80% accuracy in their reported assessment at this time.

16-bit Landsat 8 QA Band – Read bits from RIGHT to LEFT <__ starting with Bit 0																
BIT	**15**	**14**	**13**	**12**	**11**	**10**	**9**	**8**	**7**	**6**	**5**	**4**	**3**	**2**	**1**	**0**
DESCRIPTION	Cloud Confidence		Cirrus Confidence		Snow/Ice Confidence		Vegetation Confidence		Reserved for Cloud Shadow		Water Confidence		Reserved	Terrain Occlusion	Dropped Frame	Designated Fill

For the single bits (0, 1, 2, and 3):

- 0 = No, this condition does not exist
- 1 = Yes, this condition exists.

The double bits (4-5, 6-7, 8-9, 10-11, 12-13, and 14-15) represent levels of confidence that a condition exists:

- 00 = Algorithm did not determine the status of this condition
- 01 = Algorithm has low confidence that this condition exists (0-33 percent confidence)
- 10 = Algorithm has medium confidence that this condition exists (34-66 percent confidence)

- 11 = Algorithm has high confidence that this condition exists (67-100 percent confidence).

For example, a pixel with a value "58384" translates to the 16-bit binary string "1110 0100 0001 0000." Using the table above as an interpretation legend, this pixel is:

- Bit 0 = 0 = not fill
- Bit 1 = 0 = not a dropped frame
- Bit 2 = 0 = not terrain occluded
- Bit 3 = 0 = not populated
- Bit 4 = 0 = not water
- Bit 5 = 0 = not water
- Bit 6 = 0 = not populated
- Bit 7 = 0 = not populated
- Bit 8 = 0 = not populated
- Bit 9 = 0 = not populated
- Bit 10 = 0 = not snow/ice
- Bit 11 = 0 = not snow/ice
- Bit 12 = 0 = not a cirrus cloud
- Bit 13 = 0 = not a cirrus cloud
- Bit 14 = 0 = cloudy
- Bit 15 = 0 = cloudy

Certain decimal values occur regularly and can be interpreted without unpacking them into 16-bit strings and using the table above as a reference. Some common pixel values and their meanings are included in Appendix A.

Section 3 **Download and Installation**

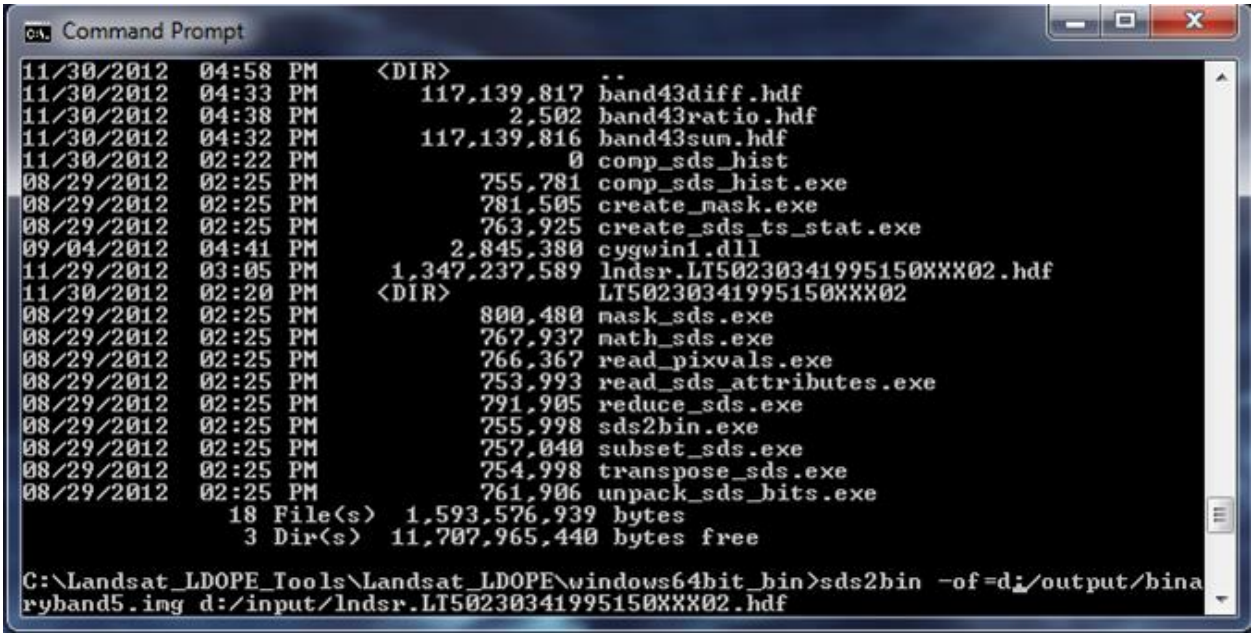
The L-LDOPE Toolbelt is available at no cost from a USGS Web site, where a compressed file can be downloaded directly to a local drive. The software is delivered in a zip file that contains the executables compiled for Linux 32-Bit, Linux 64-Bit, Windows 32-Bit, and Windows 64-Bit systems, accompanied by the source code and a readme file. Installation steps are listed below.

1. Download "Landsat_LDOPE_Tools.zip" from http://landsat.usgs.gov/L-LDOPE_Toolbelt.php.

2. Unzip "Landsat_LDOPE_Tools.zip" to desired local directory, e.g. "C:\Landsat_LDOPE_Tools."

3. Verify directory contents:
   Landsat_LDOPE_Tools
   Landsat_LDOPE
   bin
   src
   linux32bit_bin
   linux64bit_bin
   windows32bit_bin
   windows64bit_bin
   Landsat_LDOPE_readme

Each command in the L-LDOPE Toolbelt can be run directly by typing the executable name and its parameters from the respective "bin" directory. The following snapshot shows command execution from a Windows Command Prompt display.



Section 4 **Tool Descriptions**

Each of the commands in the L-LDOPE Toolbelt is detailed in the sections below. Instruction or guidance is given in the context of name, synopsis, description, arguments, examples, and authors for each tool.

4.1 unpack_oli_qa

NAME

unpack_oli_oa – Extract specified bits from the Landsat 8 OLI QA band and writes them to individual GeoTIFFs, or combines them into a single GeoTIFF.

SYNOPSIS

unpack_oli_qa -help [filename]

unpack_oli_qa --ifile=input_QA_filename --ofile=output_unpacked_QA_filename [--all=conf_level] [--fill=conf_level] [--drop_frame=conf_level] [--terrain_occl=conf_level] [--water=conf_level] [--cloud_shadow=conf_level] [--veg=conf_level] [--snow_ice=conf_level] [--cirrus=conf_level] [--cloud=conf_level] [--combine]

DESCRIPTION

Landsat 8 OLI QA bits can be extracted into individual QA bands output to multiple files, or as combinations of bits output to a single file. The output bands will refer to the QA bits (from right to left), representing the QA information which is stored in the QA band.

In some cases a single bit is used to represent quality data in the OLI QA band and in other cases two bits are used to describe conditions that may affect pixel quality.

For quality data represented by a single bit, the output values are as follows:

0 = No, this condition does not exist
1 = Yes, this condition exists

For quality data represented by two bits, the user has the option to specify the confidence levels included in the mask. The current confidence levels in the OLI QA band are as follows:

00 = Algorithm did not determine the status of this condition
01 = Algorithm has low confidence that this condition exists (0-33 % confidence)
10 = Algorithm has medium confidence that this condition exists (34-66 % confidence)
11 = Algorithm has high confidence that this condition exists (67-100 % confidence)

If the user specifies a confidence level of 'low' for a confidence field, then the output mask will be flagged as “1” (yes) if the 2-bit confidence value is low, medium, or high. If the user specifies a confidence level of 'med' for the confidence field, then the output

mask will be flagged as “1” (yes) if the confidence value is medium or high. And, if the user specifies a confidence level of 'high', then the output mask will be flagged as “1” (yes) if the confidence value is high.

The following table identifies the output quality band and how it correlates to the bits in the individual QA bands, when not using combine bits. The user may select to combine the specified QA bits into one single output file. In that case, if any of the specified QA bits meet the specified confidence level, then the output mask for that pixel will be flagged as “1” (yes).

Tool Output	QA Bit(s)	Description
_fill.tif	0	Fill
_dropped_frame.tif	1	Dropped Frame
_terrain_occl.tif	2	Terrain Occlusion
N/A	3	Reserved
_water.tif	4-5	Water Confidence
_cloud_shadow.tif	6-7	Cloud Shadow Confidence
_vegetation.tif	8-9	Vegetation Confidence
_snow_ice.tif	10-11	Snow/Ice Confidence
_cirrus.tif	12-13	Cirrus Confidence
_cloud.tif	14-15	Cloud Confidence

The tool command arguments can be specified in any order.

ARGUMENTS

-help — Display this help message. If the input filename is specified with this option, then the names of all the SDSs in the file are displayed.

-ifile — Name of the input QA file (unsigned 16-bit integer GeoTIFF).

-ofile — Basename of the output file if bit combination is not used, otherwise the full name of the output file (unsigned 8-bit integer GeoTIFF to match the user-specified quality bits).

-combine — Indicates the specified QA bits will be combined into one single output band, e.g., create an output file with all pixels that are either cloudy or water flagged “1” (yes). Default is false.

-all — Output all the quality bits (0-15) using the specified confidence level for 2-bit QA fields. Default is true.

-fill — Output the fill bit (0).

-drop_frame — Output the dropped frame bit (1).

-terrain_occl — Output the terrain occlusion bit (2).

-water	Output the water bits (4, 5) using the specified confidence level ('low', 'med', or 'high'). Default is ‘med.’
-cloud_shadow	Output the cloud shadow bits (6, 7) using the specified confidence level ('low', 'med', or 'high'). Default is ‘med.’
-veg	Output the vegetation bits (8, 9) using the specified confidence level ('low', 'med', or 'high'). Default is ‘med.’
-snow_ice	Output the snow/ice bits (10, 11) using the specified confidence level ('low', 'med', or 'high'). Default is ‘med.’
-cirrus	Output the cirrus bits (12, 13) using the specified confidence level ('low', 'med', or 'high'). Default is ‘med.’
-cloud	Output the cloud bits (4, 5) using the specified confidence level ('low', 'med', or 'high'). Default is ‘med.’

EXAMPLES

Unpack all the QA bits into their own single-band GeoTIFF files. Use the default of medium confidence (and above) for the 2-bit quality fields. The command is typed entirely on one line.

```
unpack_oli_qa --ifile=LC80340322013132LGN01_BQA.tif --
ofile=LC80340322013132LGN01 –all
```

Unpack the fill, water, vegetation, snow/ice, and cloud quality fields each into their own GeoTIFF file. The fill field (single-bit) does not require a confidence level. Water pixels will be masked if their confidence level is high. Vegetation pixels will be masked if their confidence level is low, medium, or high. Snow/ice pixels will be masked if their confidence is medium or high (the default). Cloud pixels will also be masked if their confidence level is medium or high. The command is typed entirely on one line.

```
unpack_oli_qa --ifile=LC80340322013132LGN01_BQA.tif --
ofile=LC80340322013132LGN01 --fill --water=high --veg=low --snow_ice --cloud=med
```

Unpack the fill, cloud, and cirrus quality fields each into one combined file. The fill field (single bit) does not require a confidence level. Cloud pixels will be masked if their confidence level is high. Cirrus pixels will be masked if their confidence level is low, medium, or high. The command is typed entirely on one line.

```
unpack_oli_qa --ifile=LC80340322013132LGN01_BQA.tif --
ofile=LC80340322013132LGN01_mask.tif --fill --cloud=high --cirrus=low --combine
```

AUTHOR: G. Schmidt Version 1.0, 07/08/2013

Section 5 **Use and Citation Information**

There are no restrictions on the use of the L-LDOPE Toolbelt, but please include the following citation in publication or presentation materials based on information derived from this software to credit the original development.

Roy, D.P., Borak, J.S., Devadiga, S., Wolfe, R.E., Zheng, M., Descloitres, J., 2002, The MODIS Land Product Quality Assessment Approach, Remote Sensing of Environment, v. 83, p. 62-76.

If possible, reprints or citations of papers or oral presentations based on information derived from this software are welcome at the User Services addresses included in this guide. Such cooperation will help USGS stay informed of how the software is being used.

Section 6 **User Services**

The Landsat CDRs, Essential Climate Variables (ECV), and associated software tools and interfaces are supported by User Services staff at USGS Earth Resources Observation and Science Center (EROS). Any questions, comments, or problems are welcomed through the Landsat "Contact Us" on-line correspondence form. Please indicate "Surface Reflectance Data/LAI Request" as the topic of regard. Electronic mail can also be sent to the customer service address included below, with the same indication of topic.

USGS User Services
http://landsat.usgs.gov/contactus.php
custserv@usgs.gov

User support is available Monday through Friday from 8:00 a.m. – 4:00 p.m. Central Time. Inquiries received outside of these hours will be addressed during the next business day.

Appendix A Common QA Values

Pixel Value (Decimal)	Cloud	Cirrus	Snow/Ice	Veg	Water	Terrain Occlusion	Dropped Frame	Fill
61440	Yes	Yes	Not Determined	Not Determined	Not Determined	No	No	No
59424	Yes	Maybe	Maybe	Not Determined	Maybe	No	No	No
57344	Yes	Maybe	Not Determined	Not Determined	Not Determined	No	No	No
56320	Yes	No	Yes	Not Determined	Not Determined	No	No	No
53248	Yes	No	Not Determined	Not Determined	Not Determined	No	No	No
52256	Yes	Not Determined	Yes	Not Determined	Maybe	No	No	No
52224	Yes	Not Determined	Yes	Not Determined	Not Determined	No	No	No
49184	Yes	Not Determined	Not Determined	Not Determined	Maybe	No	No	No
49152	Yes	Not Determined	Not Determined	Not Determined	Not Determined	No	No	No
48128	Maybe	Yes	Yes	Not Determined	Not Determined	No	No	No
45056	Maybe	Yes	Not Determined	Not Determined	Not Determined	No	No	No
43040	Maybe	Maybe	Maybe	Not Determined	Maybe	No	No	No
39936	Maybe	No	Yes	Not Determined	Not Determined	No	No	No
36896	Maybe	No	Not Determined	Not Determined	Maybe	No	No	No
36864	Maybe	No	Not Determined	Not Determined	Not Determined	No	No	No
32768	Maybe	Not Determined	Not Determined	Not Determined	Not Determined	No	No	No
31744	No	Yes	Yes	Not Determined	Not Determined	No	No	No
28672	No	Yes	Not Determined	Not Determined	Not Determined	No	No	No
28590	No	Maybe	Yes	Yes	Maybe	Yes	Yes	No
26656	No	Maybe	Maybe	Not	Maybe	No	No	No

				Determined				
24576	No	Maybe	Not Determined	Not Determined	Not Determined	No	No	No
23552	No	No	Yes	Not Determined	Not Determined	No	No	No
20516	No	No	Not Determined	Not Determined	Maybe	Yes	No	No
20512	No	No	Not Determined	Not Determined	Maybe	No	No	No
20480	No	No	Not Determined	Not Determined	Not Determined	No	No	No
19456	No	Not Determined	Yes	Not Determined	Not Determined	No	No	No
16416	No	Not Determined	Not Determined	Not Determined	Maybe	No	No	No
16384	No	Not Determined	Not Determined	Not Determined	Not Determined	No	No	No
16380	Not Determined	Yes	Yes	Yes	Yes	Yes	No	No
13246	Not Determined	Yes	Not Determined	Yes	Yes	Yes	Yes	No
6176	Not Determined	No	Maybe	Not Determined	Maybe	No	No	No
6148	Not Determined	No	Maybe	Not Determined	Not Determined	Yes	No	No
2592	Not Determined	Not Determined	Maybe	Maybe	Maybe	No	No	No
2592	Not Determined	Not Determined	Maybe	Maybe	Maybe	No	No	No
2308	Not Determined	Not Determined	Maybe	No	Not Determined	Yes	No	No
2144	Not Determined	Not Determined	Maybe	Not Determined	Maybe	No	No	No
2112	Not Determined	Not Determined	Maybe	Not Determined	Not Determined	No	No	No
2080	Not Determined	Not Determined	Maybe	Not Determined	Maybe	No	No	No
2052	Not Determined	Not Determined	Maybe	Not Determined	Not Determined	Yes	No	No
2048	Not Determined	Not Determined	Maybe	Not Determined	Not Determined	No	No	No
515	Not Determined	Not Determined	Not Determined	Maybe	Not Determined	No	Yes	Yes
64	Not	Not	Not	Not	Not	No	No	No

	Determined	Determined	Determined	Determined	Determined			
32	Not Determined	Not Determined	Not Determined	Not Determined	Maybe	No	No	No
32	Not Determined	Not Determined	Not Determined	Not Determined	Maybe	No	No	No
4	Not Determined	Not Determined	Not Determined	Not Determined	Not Determined	Yes	No	No
0	Not Determined	Not Determined	Not Determined	Not Determined	Not Determined	No	No	No

Appendix B Acronyms

Acronym	Description
2D	Two Dimensional
CDR	Climate Data Record
COTS	Commercial Off The Shelf
DAAC	Distributed Active Archive Center
DOI	Department of the Interior
ECV	Essential Climate Variable
EOS	Earth Observing System
EROS	Earth Resources Observation and Science
ETM+	Enhanced Thematic Mapper Plus
GCOS	Global Climate Observing System
GeoTIFF	Geographic Tagged Image File Format
HDF	Hierarchical Data Format
LDOPE	Land Data Operational Product Evaluation
LEDAPS	Landsat Ecosystem Disturbance Adaptive Processing System
L-LDOPE	Landsat-LDOPE
LP	Land Processes
MODIS	Moderate Resolution Imaging Spectroradiometer
NASA	National Aeronautics and Space Administration
OLI	Operational Land Imager
QA	Quality Assurance
SDS	Science Data Set
TM	Thematic Mapper
USGS	U.S. Geological Survey